

The trend of tree line on the northern slope of Changbai Mountain

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Abstract: In order to decipher phenomenon of tree line changing with climate variety, the trend of tree line on the northern slope of Changbai Mountain was studied. Based on the meteorological data of Changbai Mountain, the January temperature (the limiting effect for tree line) and annual mean temperature were mainly investigated. In the ecotone between *Betula ermanii* and alpine tundra, the number and diameter at ground level of *Betula ermanii* in the plots were measured. According to the correlation between diameter at ground level (DGL) and age, the diameter at ground level can represent age directly. The results showed that the distribution age of *Betula ermanii* was in the trend of decreasing with elevation rising. In recent years, the annual mean temperature near Changbai Mountain is rising, which has led to the tree line ascending.

Key words: Tree line; Temperature; Elevation; Meteorological data

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Introduction

Changbai Mountain is one of the most valuable reserves for its various natural ecosystem, especially for the altitudinal vegetation zonation. The virgin forest ecosystem in Changbai Mountain is a typical natural representative of N.E. Eurasia. There are four vegetation zones arranged from lower to higher elevation (Hao 2000). *Pinus koraiensis* broad-leaved forest exists from 500 m (altitude) to 1 100 m; dark coniferous forest exists from 1 100 m to 1 700 m; *Betula ermanii* forest extends from 1 700 m to 2 000 m and the alpine tundra is above 2 000 m. Changbai Mountain is a dormant volcano, its latest eruption happened in 1700 or so. The eruption destroyed vegetation in Changbai Mountain, especially for the alpine vegetation around the crater. The analysis for wood fossil and spore indicated that the tree line of Changbai Mountain before the last eruption was distributed in 2 200 m. Now *Betula ermanii*, as the species of timberline of Changbai Mountain, can live only in less than 2 100 m on the northern slope of Changbai Mountain. According to fossil wood analysis, the climate has not changed much in recent 1000 years (Tian 1986, 1988, 1989). So the vegetation distribution would not change much if it was not disturbed by natural disaster or human. The indexes of rain and temperature showed that the timberline should be in more than 2 100 m (Xu *et al.* 1981).

So the population of *Betula ermanii* existing now does not reach the climax population fitting the environment and it is in the trend of succeeding to the climax population.

With the global climate change, the alpine climate of Changbai Mountain is changing too (Zhao 1998). Climate changes have caused marked changes in species distribution and abundance (Dai 1998). In recent shorter time these climate changes have caused changes in community structure, growth, and productivity; and caused changes in vitality and physiognomy of ecosystems and moisture conditions and availability; in longer time these changes have also caused changes of species distribution, especially the change of tree line (Annika *et al.* 1999). Tree line is an ecotone defined by temperature during the growing season and by precipitation and snow-pack characteristics (Michael *et al.* 1998). Tree line is sensitive to climatic changes because many of the tree species are at or near their ecological tolerance limits. Climatic prerequisites for forest growth change gradually from *Betula ermanii* forest to Alpine tundra throughout the northern slope. Generally, because of the effect of precipitation decreasing, the temperature increases with elevation increasing. Along such altitudinal gradients, continuous and abrupt changes in regional vegetation pattern can be observed. In the ecotone between *Betula ermanii* forest and Alpine tundra, the distribution elevation of *Betula ermanii* is in the trend of rising with the elevated temperature. Hypothetically, this shift in regional vegetation pattern may be caused by long-term climate change (Marlow *et al.* 1994, 1998, 2000). The result would imply that climate, at least for the present, has changed significantly. Thus, a climate change may explain the elevated timberline variation. This hypothesis is validated by the phenomenon of the decreasing snow-pack at the top

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of mountain. A pronounced impact of climate on tree-ring growth is generally shown along altitudinal distribution limits of the species, e.g. the alpine part of *Betula ermanii*. Additionally, detailed analysis for the response of species growth and for a broad range of climate variability is useful in assessing responses to future climate warming.

In this paper, we evaluate tree line trend on the northern slope of Changbai Mountain according to the distribution structure of *Betula ermanii* probingly.

Study areas and methods

The research areas lie in the ecotone between *Betula ermanii* forest and alpine tundra. The soil is mountain sody forest soil and the vegetation includes mainly Compositae, Gramineae, Ericaceae, Caryophyllaceae and Ranunculaceae. It is very cold in winter and the annual average temperature is from -2.3 to -3.8 °C, the period of highest temperature and the lowest temperature are in July and in January, respectively. Since the link between climate and regional vegetation zonation is well established, the annual lowest temperature and the accumulated temperature are the factors limiting *Betula ermanii* distribution. The meteorological record time in Changbai Mountain began only from 1982, so we adopted the meteorological data in Dunhua, which extended from 1953 to 1990 additionally. Because there is no distinct terrestrial barrier the distance between Dunhua and Changbai Mountain is not too long, the meteorological differences between two places are not too obvious. The results of annual average temperature are shown in Fig.1. According to Fig.1, the annual average temperature is in linear correlation with year ($r=0.4414$), it is in the trend of rising. Fig. 2 showed the trend of January temperature's correlation with year. The result showed that temperature in January was also in linear correlation with year ($r=0.1587$). The change trend of January temperature in Changbai Mountain from 1982 to 1998 was similar to that in Dunhua ($r=0.2636$). From Fig.1, Fig.2 and Fig.3, we can see the annual mean and January temperature are all in the trend of rising.

Betula ermanii is a climax species in alpine zone and the timberline tree on northern slope of Changbai Mountain. The source of generation depends on seed mainly. In the area of its distribution, *Betula ermanii* can spread mainly by wind. Wind speed in alpine zone is the hardest in January and gentle in August. The bad weather conditions and hard wind lead to density of *Betula ermanii* trees to be scare. Age is well correlated with diameter at ground level, the correlation equation is:

$$Y=32.195+6.017D, r=0.98 \text{ (Liu 1989).}$$

Where: Y -- the age of tree; D -- the diameter at ground level.

The spout species grow similar to the seedling species,

so the age is also well correlated with diameter at ground level. To protect the existing *Betula ermanii* and research more efficiently, the age of *Betula ermanii* was replaced by diameter at ground level. On northern slope of Changbai Mountain, we selected two ditches where wind speed was gentle according to *Betula ermanii* characteristic. Then we began to find the first species of *Betula ermanii* and set two sampling belts centered to the two ditches from the top of Mountain. Both belts were 10 m wide. In the belts, we set sampling fields, which was 2 m long each. The number of *Betula ermanii* in each plot, the diameter and height of the biggest one in each plot were recorded. The sampling belts were ended in the climax forest of *Betula ermanii*.

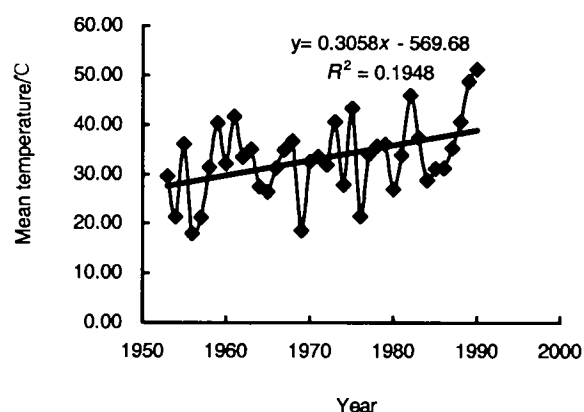


Fig.1 Chang trend of annual mean temperature from 1953 to 1990

Results and analysis

The first sampling belt lies on an open slope and it is easily influenced by surrounding. The results in Fig. 4 are that the DGL (diameter at ground level) of *Betula ermanii* is in the trend of decreasing with elevation increasing. The DGL is in the linear correlation with altitude and the correlation index is 0.16. According to the correlation between DGL and age, the diameter at ground level (DGL) can represent age directly. So the distribution age of *Betula ermanii* is in the trend of decreasing with elevation rising. Fig.6 is the result of another sample belt. This sample belt has a little different from the first one because this belt is insulated from outside and is affected less comparatively. From Fig. 6, we can see the same result as in Fig. 4 and the linear correlation index is 0.256. All the results showed that the distribution age of *Betula ermanii* was in the trend of decreasing from 1900 m to the limiting elevation of *Betula ermanii* distribution. In the place of higher elevation, *Betula ermanii* is younger, which means the limiting line of *Betula ermanii* is climbing along altitude. Though the factors limiting *Betula ermanii* are various and the relationship between limiting factors and *Betula ermanii* distribution is complex, the whole age structure of *Betula ermanii* is identical with the climate change and the change

of snow-pack on the top of mountain.

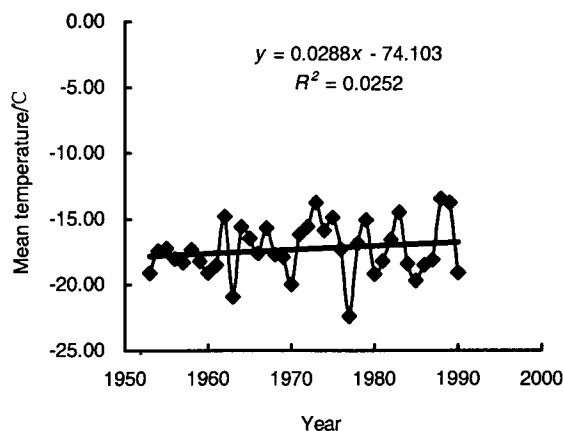


Fig. 2 Chang trend of mean temperature of January from 1953 to 1990

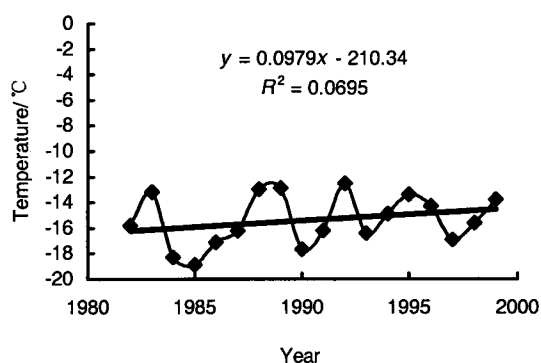


Fig. 3 Chang trend of mean temperature of January from 1982 to 1999

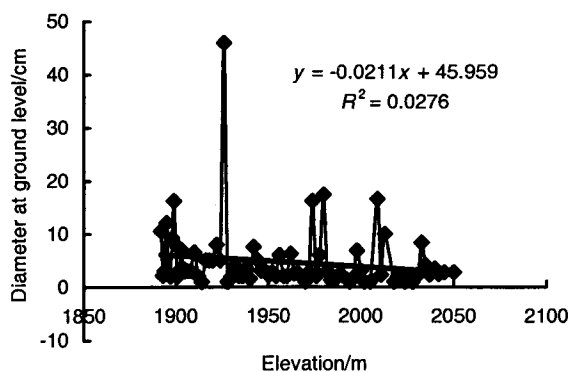


Fig. 4 Chang trend of individual diameter at ground level with elevation

To know further the distribution of *Betula ermanii*, we analyzed the number of individuals in each plot along elevation. The results showed that there were fewer individuals of *Betula ermanii* in the plot that lies in higher

elevation. Fig.5 is the individual number distribution pattern of *Betula ermanii* in a sample belt. We can find the number of *Betula ermanii* is in the linear correlation with elevation, r is 0.644 4. On the other hand, the seedlings of *Betula ermanii* are centered to an old individual, which illustrates that *Betula ermanii* reproduce by seed.

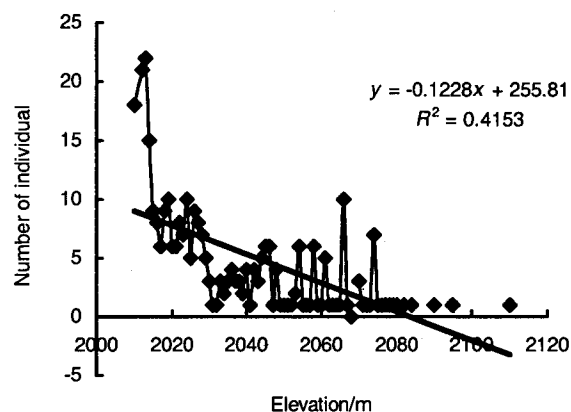


Fig. 5 Number of *Betula ermanii* in each plot with the elevation

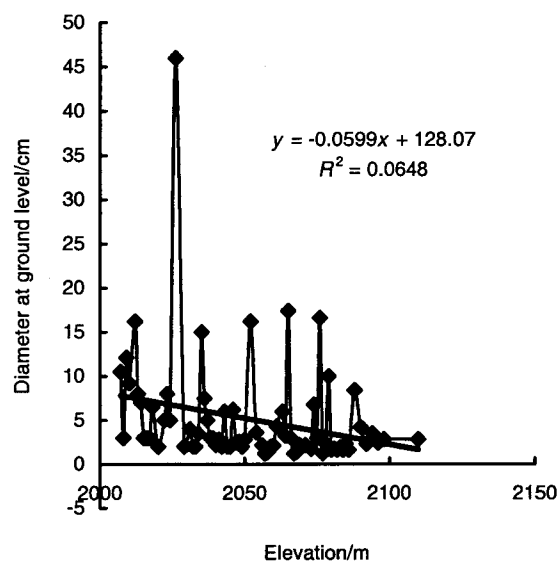


Fig. 6 Chang trend of individual diameter at ground level with elevation

Discussion

The *Betula ermanii* distribution pattern along altitude showed that the density of *Betula ermanii* became scarcer and the age became younger with altitude rising. These distribution patterns just showed that the limiting line of *Betula ermanii* was climbing along the altitude and the tree line was in the trend of rising. There are two main reasons, which can account for the rising tree line. Firstly, the temperature is rising, just as shown in Fig. 1, 2, 3. Secondly, the vegetation destroyed by eruption in the past is restoring to the original one. Without interruption of human, the

vegetation in Changbai Mountain is in the trend of restoring to the vegetation before eruption destruction, and the rising temperature will lead to higher tree line if given enough time.

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